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ABSTRACT

This paper investigates changes in attitude using an adapted version of the Fennema-Sherman Mathematics Attitude Scales (F-S MAS). Writing samples, such as student math autobiographies, journals, and responses to mathematical problems, were collected, and student evaluations of teaching across semesters were reviewed. Over three semesters, a modified F-S MAS survey was administered to students in reform and non-reform sections. Pre- and post-course attitude scores were compared across groups. It is concluded that attitudes toward mathematics are based on long-term interactions with the subject and mathematics teachers; they take a long time to develop and are hard to change. (Contains 18 references.) (ASK)

Student Attitudes in a Reformed Mathematics Classroom

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Introduction

There has been considerable call for the reform of mathematics classroom teaching on the K-16 levels (e.g., Cipra, 1992; Leitzel, 1991; National Commission on Excellence in Education, 1983, National Council of Teachers of Mathematics [NCTM], 1980, 1989, 1991). However, such efforts are multifaceted, complex, contextual, and often lack consensus. Within the context of this controversy, the National Science Foundation (NSF) put forth a call for proposals that sought to form collaborative relationships between institutions of higher learning within a given region (i.e., city, state, or part of a state) and between faculty within Liberal Arts and Sciences and Education. These relationships were thought to be catalysts for change in the ways in which prospective teachers experience mathematics and science instruction.

The reform of post-secondary mathematics courses is central to NSF's Collaborative projects. As part of the New York Collaborative for Excellence in Teacher Preparation (NYCETP), the first author revised the required mathematics course for prospective elementary teachers at City College (CCNY) of the City University of New York (CUNY). Course modifications included math journals/writing exercises, activity-based lessons, and collaborative learning projects. The goal was to facilitate student learning and to model instructional practices called for in the NCTM Standards documents (1989).

To evaluate the impact of these revisions, we investigated changes in attitude using an adapted version of the Fennema-Sherman Mathematics Attitude Scales [F-S MAS] (Fennema & Sherman, 1976); collected writing samples such as student math autobiographies, journals, and responses to mathematical problems; and reviewed student evaluations of teaching across semesters. Over three semesters, a modified F-S MAS survey was administered to students in "reform" and "non-reform" sections. Pre- and post-course attitude scores were compared across groups. In this paper, we provide a context for the work of NYCETP and the specific reformed mathematics course (Math 185), and course revisions undertaken, as well as the difficulties encountered with reforming the course. A review of the literature will be provided to examine and bring together studies that set out to investigate attitude changes in the context of reform and to review studies that have used the F-S MAS. Both statistical analyses of data from the F-S MAS and anecdotal evidence from student writings will be examined to help elucidate the impact of the reform in this classroom. Conclusions and recommendations will be drawn from the context in which the reform was enacted and both quantitative and qualitative data.

Context and Reform

Context of the Collaborative

The New York Collaborative for Excellence in Teacher Preparation (NYCETP or "the Collaborative") is a project involving five four-year colleges and several two-year community colleges of the City University of New York (CUNY) and New York University (NYU). The project was funded by the NSF, with additional support from the participating institutions. It is presently in its fifth year of a five-year grant, and data for this study were collected during years two and three (1996-1997, 1997-1998). The main goals of the Collaborative include: (1) collaboration within and between the five campuses of CUNY and NYU; (2) faculty development emphasizing curriculum and teaching standards such as the NCTM (1989, 1991) and the National Research Council (NRC, 1996) Standards documents; and (3) the design and development of mathematics and science content and education courses for students preparing to become teachers. Although there are other important goals (e.g., recruitment of math and science teachers and increasing numbers of underrepresented populations within the teaching profession), these specific objectives form the basis for the Liberal Arts and Science course reform and programmatic change that are primary to the NSF CETP's purpose.

NYCETP includes colleges from a large public urban institution and a large private urban university. The five CUNY campuses are situated within four of the five boroughs of New York City (Brooklyn College in Brooklyn, Lehman College in the Bronx, City College of New York and Hunter College in Manhattan, and the College of Staten Island on Staten Island), and NYU is located in Manhattan. The teacher education program at each of the participating universities is focused mainly on urban education.

Although each of these colleges is situated within New York City, they are located within vastly different areas of the city. CUNY campuses draw almost solely from the New York metropolitan area, while NYU draws its student population from both New York and nationwide. Thus, the student bodies of each are quite different. Two of the CUNY campuses, Lehman College and City College are located in predominantly multiethnic areas, and at these two colleges students are mostly second language learners. On the first New York State teacher licensure exam, the Liberal Arts and Sciences Test (LAST - Basic Skills; 1997), both of these colleges had a high percentage of failures.

Background of the College and the Course

CCNY, a senior or four-year college within CUNY founded in 1847, is the oldest among the twenty public institutions that make up CUNY, which was established in 1961.

The original mandate of the College was to provide the best possible education to the children of the poor and working-class people and to open to all new immigrants the opportunities of America. And indeed, since its inception, the College has endeavored to fulfill its promise to advance the lives of its students, many of whom have been the first in their families to consider attending college. The campus is located in a section of Manhattan with large minority and new immigrant populations. In fact, the College has always viewed its mission, along with Excellence, as Access. The student population, especially in the course in which the study was conducted, is largely female, about 80% African-American and Hispanic. Many students work demanding jobs outside of school, have children, and are sometimes the heads of single-parent households.

At the time of this study, CCNY consisted of the College of Liberal Arts and Sciences and four separate professional schools, one of which was Education. Preservice elementary teachers were to take one course in the Mathematics Department, Math 185, early in their career. The prerequisite for 185 was the completion of a remedial math course or placement at a level of about one and a half years of academic high school mathematics. Upon completing certain requirements, among them this course, the students were to begin their professional training in education. Toward the end of their undergraduate career, they were to take an education methods course, How Children Learn Mathematics, in which, drawing upon the mathematical knowledge gained in 185, they were to explore the growth of children's mathematical knowledge.

As the subjunctive voice used in the antecedent paragraph conveys, the imperfect reality did not mirror the orderly theory. Education and mathematics were departments in **separate branches** of the College, with the usual incomplete communication among these branches. Education never requested changes in the course, and Mathematics never realized that changes were necessary for reasons detailed next. Historically, the course had been designed as a finite math course for humanities students. Thus, Math 185 was not only a requirement for preservice teachers but also served to fulfill part of the science core for non-science majors. Thus, a fortiori, some of the mathematics in the course was not geared towards the need of prospective teachers, nor was the course structured to conform to the NCTM or the New York State Department of Education standards. The non-education students who **chose** to take the course as part of the core generally had a much stronger mathematical background and more positive attitude toward mathematics than the education students, who, as a group, feared the course, yet were **required** to take it. The education students registered in all day-session sections of Math 185 during the three semesters of the study achieved an average grade of "C" ($\underline{M}$ = 1.96 on a four-point scale). The non-education students in the same classes had attained a course grade of "B-" ($\underline{M}$ = 2.79 on a four-point scale).

Additionally, the prerequisite remedial mathematics course was inadequate preparation for Math 185. It was not sufficient to enable many of the weaker students to meet the demands of the subject matter in the latter course. Consequently, the material in Math 185 was too often taught using a simplified, algorithmic approach. Finally students avoided the course until a semester before graduation, when this course was the only obstacle that lay between them and a diploma. The course was in serious need of renovation and the NYCETP decided, in the person of Shelley Ring, to undertake the project. The reform process will be described in the next section.

Context of Course Reform

At the start of our study, Math 185 was the single college-level mathematics requirement at CCNY for prospective elementary teachers. As such, it was both crucial for, and intensely feared by, many of its resident education students. However, the course was firmly housed in the Mathematics department, not Education, and politically needed to remain, first and foremost, a mathematics course. The topics studied in the course included set theory, historical numeration systems and number bases, simple number theory, rational and real numbers, probability and some problem solving/pattern recognition using various techniques including the concept of functions and techniques of algebra.

The revision began cautiously (see Table 1 for the timeframe of the reform). During spring 1996, the semester prior to data collection, Ring taught the course with one modification: the incorporation of student journals. She believed strongly in the oft-neglected second NCTM standard (1989), which states, "the study of mathematics should include numerous opportunities for communication" (p. 26). In their entries, the students reflected on their understanding of and reactions to the topics taught that week. The journals were returned weekly, with comments, and so a dialogue between teacher and students developed. Many positive results for both students and the instructor can result from such an implementation of writing in the mathematics classroom. These include students expressing their feelings, knowledge, processes and beliefs about mathematics (Borasi & Rose, 1989) and greater conceptual understanding and procedural knowledge (Jurdak & Zein, 1998). In the present case, several things rapidly became clear. The fear and loathing of mathematics by the members of the class had not been overstated. Also, students did not truly learn what the instructor thought she had taught. Finally, many of the students had difficulty explaining even the concepts that standard assessments (tests) showed that they had "learned." They could solve problems but not explain clearly the process that they used to arrive at their solution, a serious deficit for a soon-to-be "professional facilitator" of explanations.

By fall 1996, the instructor began to introduce further modifications to incorporate more of the philosophy and goals of the NCTM standards (1989), in particular increasing emphasis on cooperative work and the use of manipulative materials. These elements included activity-based lessons, collaborative learning exercises, and journal writing. Cooperative learning, primarily consisting of group problem-solving sessions, fostered active learning and drew out some of the more reticent students. The students particularly enjoyed working with manipulative materials. However, since many of the problems posed were non-routine, some of the students found them too difficult and so did not, even with encouragement, fully participate in the group learning process.

In conjunction with her work to revise Math 185, Ring had been fiercely lobbying the "powers-that-were" for a stronger prerequisite to precede this course (i.e., a second college-level course, Quantitative Reasoning). Her request for a requirement of two college-level courses was a modest proposal compared to recommendations by the NCTM (1991), the MAA (Leitzel. 1991), and other scholars (Cipra, 1992). These organizations and groups of scholars call for at least nine semester hours of undergraduate mathematics for the preparation of prospective elementary teachers and courses that substantially differ in content and pedagogy from those offered in a traditional mathematics department. The prerequisite assumed for these courses is three years of college preparatory math in high school.

Ring was beginning to feel what her students needed most was a course that gave them what Ma (1999) calls a "profound understanding of fundamental mathematics" (p.120). By this phrase, the author means a thoroughness of mathematical knowledge of **elementary school mathematics** that allows the teacher to implement a curriculum that is *conceptually oriented* – a basic assumption of the current reform in mathematics education. However, there was no real chance of changing the subject matter of the course to directly address these issues. The core placement and the fact it was the only college mathematics course taken by the students meant its topics needed to remain "advanced." To make sure the course did not lose the full flavor of mathematics at any stage of the revision, Ring decided to implement the revisions slowly and in discrete stages. Thus, members of the mathematics department could evaluate each piece separately, a process that might ease faculty into the unfamiliar territory of this new approach.

Also during fall 1996, the instructor began to work with education faculty to develop activities to reinforce mathematical concepts with concrete situations, while also teaching about the use of manipulative materials in the development of the mathematical concepts. In her [eventual] course description, Math 185 remains fairly conventional in terms of topics taught, and, indeed, no particular approach is mandated in many of the lessons. However, there is ample opportunity for extra problem-solving and collaborative work built into the course. During this semester, she designed four full-period activities to be done by students in a yet-to-be-created math resource room.

Each activity highlighted important aspects of one of the four main subject areas of the course (i.e., set theory, number bases, primes/factors/multiples, and probability). The set theory activity began with students using attribute sets and sorting circles and built to the creation of complex Venn diagrams. The number base activity had students using chips as 'money' in different countries, with the goal of understanding the nature of positional numeration. The activity on primes, factors and multiples required students to construct graphs relating to these ideas. The probability activity focused on the crucial relationship between the theoretical and empirical definitions of probability, and in particular, the Law of Large Numbers. Additionally, Ring created/compiled twelve brief collaborative learning exercises, which differed from the usual classroom experiences by either being more challenging problems or "mini-activities" that required no manipulatives and could be completed in a regular classroom on a weekly basis. The problems included challenging survey problems or puzzles in number theory. The activities could be games for children with questions about the content and pedagogy of the games to be answered by the college students. Many of these collaborative exercises were piloted in Ring's Math 185 class during spring 1997, borrowing materials and appropriating space on the fly.

The next semester, Math 185 instructors were encouraged to incorporate the activities, and by spring 1998 the chair of the Mathematics department mandated that all instructors were to include them as part of the course. Prof. Ring assisted all activity sessions for these two transition semesters, attempting to encourage each instructor to gradually replace Ring as the main facilitator. All mathematics instructors were "formally" invited to the full-period activities, through notices, phone calls and email.

(Humorous notices helped pique curiosity.) About fifteen members of the department attended one or more of the sessions and the response was, in the main, quite positive. One senior member of the department said, "What I saw deserved videotaping. There was terrific interaction and exploration...."

A final "reform" aspect of the course evolved from the very first innovation: the use of journals. Beginning spring 1997, students were expected to submit written answers to four or five "thought" questions each week, as well as an initial "math autobiography," extended writings based on the four activities, and a final course summation. The writing component has been the least popular change with the faculty that teach the course, with most of them refusing to give more than a passing nod to the idea that students must be required, early and often, to defend their ideas in cogent, well-phrased explanations. Shelley Ring felt that this requirement was particularly relevant and challenging for many students at CCNY for whom English is a second language.

During spring 1998, a series of transformations swept the education program at CCNY, vindicating and assisting the modifications made in Math 185. The NYS Education Department mandated the introduction of a second math course for prospective elementary teachers. Thus, the College implemented a Quantitative Reasoning (QR) course to precede Math 185. Students then were required to take both the new QR course and Math 185 before being admitted to the education program. Thus, students could no longer leave these courses to the end of their undergraduate careers. Further, a new integrated science core was created, so that Math 185 now need only serve education students. Finally, by the end of the semester, Ring negotiated the creation of a dedicated mathematics resource room.

On paper, the course had been reformed and the students should have been entering it early in their careers, prepared for the demands of the material. However, the wheels of change grind exceedingly slow. Day session instructors were provided with the new course materials. However, as they taught, they might not include all of the full activities or many of the mini-activities because of "time pressure." Additionally, for the most part, they have not included the writing exercises because of their belief that such material does not belong in a math class. Finally, most of the students in Math 185, through fall 1999, had not taken the QR course because they were not subject to the new prerequisites. Therefore, it is still exceedingly difficult to ascertain just how much reform has truly taken place.

Attitudes toward Mathematics in the Context of Reform

Efforts to impact the teaching of mathematics on the elementary and secondary levels and teachers' attitudes toward mathematics as a domain have varied in scope and substance. Several studies have examined changes in preservice teachers' attitudes toward mathematics following the development and implementation of whole sequences of courses for preservice teachers (McDevitt, Hiekkinen, Alcorn, Ambrosio, & Gardner, 1993; Gibson, Brewer, Magnier, McDonald, & Van Strat, 1999) and the implementation of integrated mathematics courses (Rieck, Clark, & Lopez, 1995). Others have taken a different approach to this issue through the development of constructivist-oriented inservice programs (Simon & Schifter, 1993). Each of these studies measured the effect on student perceptions of the courses taken or mathematics in general, and together these studies have resulted in mixed outcomes.

Following is a discussion of the methods and reforms each of these groups of scholars has implemented in an attempt to better understand the prospects for and factors that facilitate or impede such efforts.

McDevitt et al. (1993) evaluated the impact of a comprehensive sequence of courses in mathematics and science for prospective elementary school teachers. This sequence of courses included science and mathematics content courses for elementary teachers, methods courses in math and science, and courses in traditional areas of educational theory (i.e., equity issues and educational psychology). The course sequence was carefully planned so that the content of previous courses may be drawn upon in subsequent courses, thus facilitating student efforts to make connections between the content in math and science and allowing for greater depth of content development. Two cohorts enrolled in the program, and two matched control groups participated in intensive interviews, selected observations, content analysis of course and project materials, attitudinal measures, and measures of students' beliefs about desirable teaching characteristics. For our purposes, we will concentrate here on the attitudinal changes resulting from these efforts.

Attitudinal instruments included the Fennema-Sherman Mathematics Attitude Scale and the Science Attitude Scale, which was derived by substituting science for mathematics in the items of the F-S MAS, among others (McDevitt et al., 1993, p. 599-601). ANCOVA was used to compare differences between control and project student groups on post-treatment attitudes while accounting for pre-treatment attitudes toward mathematics. Both cohorts of project students reported more positive attitudes toward teaching mathematics and science, and the first cohort reported more positive attitudes toward science than the control group. Neither group reported differing attitudes toward mathematics as a domain. However, "ethnographic data and other knowledge-based instruments indicated that project students did become committed to teaching in a manner that encourages both boys and girls to learn and pursue science and mathematics" (p. 607). Thus, although the students' attitudes were not found to differ significantly, anecdotal evidence supports the efficacy of such a treatment. Perhaps these attitudinal surveys are not powerful enough to produce evidence of change in attitudes or treatments of such duration are not sufficiently powerful to produce changes in deep-seated beliefs such as one's attitude toward mathematics.

In a similar study, program administration undertook a comprehensive program of study for paraeducators in an urban, two-college collaboration for teacher training of adults of diverse socioeconomic, linguistic, and ethnic backgrounds who are already immersed in the school system. "The primary goal was for paraeducators to experience mathematics content using constructivist instructional approaches in the hope that this would improve their attitudes toward mathematics" (Gibson et al., 1999, p. 3). The program components consisted of technology enhanced curriculum, course content emphasizing rich cultural and racial diversity, constructivist pedagogy, infusion of state frameworks where possible, and development of learner outcomes and competencies (p. 6). Two pre-college algebra classes (Algebra I and II) were developed to positively impact the students' preparedness for a subsequent college-level course, Math for Early Childhood/Elementary Teachers.

All participants periodically completed two questionnaires and took part in focus groups. The Revised Teacher Attitudinal Survey was used to document changes in attitude, while the Instructional Strategies Survey was used to document instructional strategies used in the courses in which the students were enrolled. In addition, the course instructors were interviewed to obtain their views on the courses. Attitudinal changes were examined following each course and following the completion of all three courses. Although no significant differences in attitudes were found between pre- and post-course following any of the three courses, there was a consistent trend toward increasingly positive attitudes over the three courses. Consequently, there was a significant positive change in attitudes as a result of the three courses combined. "UPDATE Scholars who started with very low level mathematics skills and who took two developmental mathematics courses followed by Math for Early Childhood/Elementary Teachers were the only students who showed a significant improvement in their attitudes toward mathematics over time" (Gibson et al., 1999, p. 12). More fine-grained analyses indicated that there was considerable change in students "views about mathematics" while their perceptions of "being good at mathematics," "learning mathematics," and "teaching mathematics" did not change considerably over time. These latter three subscales might be thought to represent components of self-concept that are less easily altered by a sequence of three mathematics courses.

These studies included at least three courses after which the impact of these experiences showed results. The effects of less comprehensive efforts such as the revision of only one mathematics course have also been examined. Rieck et al. (1995), in the context of an NSF-funded teacher collaborative project similar to that of the present study, attempted to impact student knowledge of mathematics, student attitudes toward the domain, attrition rates, and perceptions of satisfaction. Freshman students enrolled in either a standard Algebra for College Students or a reform-based course called Integrated Collegiate Mathematics. Innovations in this latter course included the use of everyday contexts to situate the mathematical content; the use of "real-world" problem solving and cooperative learning; and the integration of frequently disparate areas of mathematics including algebra, geometry, statistics, probability, and data analysis.

An attitudinal measure was developed to directly model those attitudes proposed by the NCTM Standards documents (1989, 1991) as important for teachers of mathematics. These included, for example, believing that doing mathematics can be an enjoyable experience, believing that everyone can learn mathematics, believing that mathematics is useful and necessary in everyday life (Rieck et al., 1995, p. 7-8). Comparisons of pre- and post-course attitudes showed that while there was no significant attitude change in the traditional mathematics course, there was a significant positive change in attitudes for the students in the reformed mathematics class.

The impact of such programs is questionable if we are seeking long-term changes in teacher behaviors. That is, if teachers' behaviors are to be impacted, perhaps we need to think about efforts on the initial certification level as only the beginning. Inservice programs that help teachers better understand constructivist pedagogy and mathematics content may have a more long-lasting impact. Simon and Schifter (1993) developed the Educational Leaders in Mathematics program, an intensive two-week summer institute and weekly classroom follow-up visits to support the development of experienced teachers in using constructivist pedagogy in their mathematics classrooms. These authors investigated the impact of this program on the attitudes, beliefs, and achievement of these teachers' students and on the quality of instruction of these teachers. Data was gathered through surveys, standardized tests, and teachers' reports of student change.

Attitude data consisting of students' responses to a likert-type questionnaire including feelings about mathematics and its importance were collected for three consecutive years. Significant positive effects were found for elementary students whose teachers were involved in this program. However, no significant impact was found for the secondary students. In addition, these authors investigated student perceptions of the importance of specific behaviors in learning mathematics. "Both elementary and secondary students' scores increased on items such as, 'It is important to be creative,' and 'It is important to try new things to see how they work.' Rote behaviors such as 'writing down what the teacher says' became correspondingly less important" (Simon & Schifter, 1993, p. 335). Attitudinal changes on the elementary level may be easier to bring about since secondary students have had more time to develop negative attitudes toward mathematics. This work is significant in that it provides evidence that efforts to change inservice teachers' behaviors can directly impact student attitudes and beliefs.

Each of these studies provides evidence of the potential impact of efforts to help teachers better understand mathematics and the teaching of mathematics. Two studies showed attitudinal changes following a sequence of mathematics courses that included appropriate reforms (Gibson et al., 1999; McDevitt et al., 1993), while a third study found changes in preservice teachers' attitudes toward teaching mathematics but not changes in attitudes toward the domain (Rieck et al., 1995). Potentially more important, Simon and Schifter (1993) found changes in elementary students' attitudes whose teachers had taken part in a long-term inservice program. It is within this context that we examined preservice teachers' attitudes toward mathematics preceding and following participation in a reformed mathematics course.

Methods

Participants and Procedures

All students in selected sections of Math 185 were asked to participate by filling out the Mathematics Attitude Questionnaire. The survey, an adaptation of the Fennema-Sherman Mathematics Attitude Survey (Fennema & Sherman, 1976) discussed below, was presented to the students by their professor during the first and last weeks of each semester. During fall 1996, three (3) classes participated; during spring 1997, two (2) classes were included; and during spring 1998, three (3) classes participated. During the first two semesters, Prof. Ring, who implemented the revised curriculum as described above, taught two of the sections. Three (3) sections were taught by faculty other than Prof. Ring and will be considered control classes. During the spring 1998 semester, two sections adopted the revisions originally developed by Prof. Ring and one section served as a control group. Therefore, a total of four sections (N = 58 students) of the reform-based Math 185 sections and four sections not considered to be reformed (N = 54 students) participated. The numbers of students within each section who completed two times of assessment during each semester were somewhat limited. Attrition within classes decreased the total number of individuals whose responses could be analyzed.

Fennema-Sherman Mathematics Attitude Scale (F-S MAS)

The Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976) was constructed as a measure of affective components that have been shown to impact "the amount of effort one is willing to exert to learn mathematics but also has great influence on the election of mathematics courses beyond minimum requirements in secondary school" (p. 325). There are nine subscales on the original F-S MAS: The attitude toward success in mathematics scale (AS); The mathematics as a male domain scale (MD); The mother (M)/father (F) scale; The teacher scale (T); The confidence in learning mathematics scale (C); The mathematics anxiety scale (A); The effectance motivation scale in mathematics (E); and The mathematics usefulness scale (U). Although factor analysis of these scales did not result in an exact fit to the scales suggested by Fennema and Sherman (1976), these scales have been shown to be reasonably reliable (Melancon, Thompson, & Becnel, 1994).

From these nine scales, we chose six items from each of six subscales (Appendix A): confidence, attitude, math as a male domain, usefulness of math, anxiety, and effectance motivation. Item scoring resulted in lower individual item scores being indicative of greater agreement with the item. The following interpretations for the various scales result:

1. Confidence: Lower scores indicate greater confidence (or security within the domain); Higher scores indicate less confidence.
2. Attitude: Lower scores indicate a positive attitude toward being considered a good math student; Higher scores indicate a negative attitude toward doing well in math.
3. Male Domain: Lower scores indicate the belief that males and females can

perform equally well in math; Higher scores indicate the belief that math is predominantly a male domain.

4. Usefulness: Lower scores indicate the belief that math is a useful domain; Higher scores indicate a belief that math is not a useful domain.
5. Anxiety: Lower scores indicate less anxiety (or more ease within the domain); Higher scores indicate greater anxiety.
6. Effectance Motivation: Lower scores indicate greater enjoyment in and motivation to study math; Higher scores indicate less enjoyment in and motivation to study math.

Results and Conclusions

Mathematics Attitude Questionnaire

Reliability estimates for the three-semester total sample (N = 112) indicated similar trends. Overall, reliability estimates for several subscales of the scale were not satisfactory (Table 2). Alpha coefficients for the total scale and the confidence and anxiety scales, only, were of acceptable levels over the three semesters during which the survey was administered. Consequently the confidence and anxiety subscales were combined to produce a more robust measure of the students' ease within the domain of mathematics. Acceptable reliability estimates were also determined for this combined scale. In addition, the usefulness subscale attained reasonably high reliability values.

Class and group (i.e., treatment vs. control) pretreatment differences were tested using ANOVA analyses. There were no significant pretreatment differences due to class (total sample -- N = 112). However, there was a significant difference due to class for the students' reported confidence level following their participation in the math course,

$F(7,104) = 64.15$, $p < .05$. There was one significant difference between the treatment and control groups prior to taking the mathematics classes. Students in the treatment group reported more positive attitudes toward being considered a good math student (M = 10.60, SD = 3.48) than did the students in the control group (M = 12.06, SD = 3.40), $F(1,110) = 58.97$, $p < .05$. This difference remained stable over time, $F(1,110) = 73.45$, $p < .05$, and was the only significant difference at either time.

Although not statistically significant, there was a trend toward better overall attitude toward math in the treatment group (M = 75.59, SD = 19.17) than the control group (M = 81.91, SD = 20.72) following the course. A comparison of the means for these two groups indicates that the treatment group reported somewhat lower mean scores on the confidence, attitude, and usefulness subscales (Table 2). These differences are not significant but show a trend in the expected direction. That is, the students in the treatment group when compared to those in the control class reported somewhat more positive overall attitude, confidence, and attitude toward being considered a good math student, and reported the belief that math was more useful.

Analysis of covariance procedures were used to test group differences on Time 2 total score and individual subscale totals while accounting for Time 1 reported scores. As would be expected, in most cases Time 1 data accounted for a significant amount of the variance in the dependent variables. With few exceptions, the treatment and control groups were not found to significantly differ from one another after Time 1 responses were taken into account. However, the treatment group (M = 12.93, SD = 5.08) was found to be significantly more confident or secure within the domain of mathematics than the control group (M = 14.50, SD = 5.58) once their pretreatment scores were controlled for statistically, $F(2,109) = 62.58$, $p < .05$.

Discussion of Anecdotal Evidence from Student Writings

Revising and teaching the modified versions of Math 185 have been unlike any other professional experience for the first author. A lot of sweat, tears and heart have gone into the planning and execution of the reform of Math 185. When the second and third authors approached her with the idea of running a pre- and post-course attitude survey in the course, Shelley Ring accepted with trepidation. In the process of reading their journals, the first author has come to realize that the students have very mixed feelings about the changes in the course. The authors would like to use this section to discuss some of this anecdotal evidence of student attitudes gleaned from their journals over the course of these semesters.

At the beginning of each semester, most of the students, even those who were to exit the course with a grade of "A", felt that, at best, "math was a class to endure" to be compared with, by a different student, "laundry or dishes – not that hard or painful once it is finally done." A third student who also earned an exemplary final grade wrote that she had "only a few memories of my [her] early math experiences and they are all bad." Needless to say, the weaker students were even more vocal about their negative attitudes toward the subject, stating that they had always learned by rote memorization with little understanding. The time was certainly ripe for improvement.

There were, however, a number of factors that hampered the implementation of the reform. When asked in their initial journal to discuss their workload during that semester, most of those who answered said that numerous activities and obligations filled their lives. The vast majority had jobs, some full-time, and had families including one or more children. Many of the women with children headed single-parent households. Others said that they were taking a large number of credits that semester because they needed to finish their degree quickly. A very common complaint from their summary evaluations was that the course was too much work. Some reported, claiming that there was too little time to complete all of the required work, that the time spent in class should have been extended by either increasing the number of hours per week or requiring an additional semester. The creation of the new prerequisite QR course has ameliorated the problem since some of the material has indeed been transferred to this new course. As mentioned before, during the period covered by our study, the QR course had not yet been implemented.

Part of the problem may have also been the revision process. Since the course was to remain within the mathematics department and was to serve students not majoring in education, the number of topics included could not be reduced. As a result, the reform elements implemented amounted to the addition of more activities without the reduction in the number of topics, which would have allowed the instructor to spend more time per topic. However, even when studying a particular topic in depth, students felt that too much was being asked of them.

Some students complained that the tests were not fair, saying that they had understood the material presented in class and in the homework, but did not understand the questions on the exams since, in their eyes, they were not sufficiently similar to those that they had answered before. The discomfort with non-standard problems was evident in the first semester of the reform when the collaborative work involved mostly complex non-routine problems. The students found these collaborative experiences frustrating rather than a bracing challenge. Students often asked whether this type of problem would be on a test. Another student wrote: "some problems were so difficult even for us as college students couldn't do some of them [sic]." They too often viewed the questions that were not just rote repetitions of problems done in class as tricks, whether they appeared on tests or on collected homework exercises. One student opined rather bluntly, "Why not just focus on the material that will come up on the final…it will give the students more direction."

A related aspect of the reform that met with mixed reactions from students was the requirement that students be able to explain the mathematics. The majority of these students had limited mathematics proficiency and few had ever been asked to explain rather than simply apply algorithms. Some students objected to being asked to demonstrate the reasons underlying certain algorithms, saying that it should be enough to know how to do something without being asked to justify the answer. One student said, "It's really annoying. You always ask us why. In math it should be enough to find the answer." However, this rigidity was by no means universal. The strongest student in one of the classes said that discovering that math was not "black and white" gave the subject "an exciting side." Another superior student echoed that the idea of one-answer "has always been a turnoff for me" and the fact that the course left "room for interpretation and creativity" was extremely satisfying. In general, the stronger students found pleasure in the fact that they could now explain and illustrate procedures that they had been able to carry out before the start of the class. The problem lay with the students who, despite prerequisites, could not perform the algorithms competently before entering a course that asked them to understand the rules on a deeper level.

One student objected that "the professor immediately assumes that you remember concepts from when you were in 6th grade." This problem is by no means unique to CCNY. Ma (1999), among others, discusses the lack of mathematical preparedness of American elementary school teachers. Indeed, it is difficult to teach effectively by explaining 'why' or illustrating 'what' without knowing 'how.'

The oft-despised requirement for explanations formed the core of the least popular change in the course: the use of writing exercises. Journals were used in fall 1996 but by spring 1997, the second semester of the study, students were expected to provide brief responses to four or five questions each week. Consistently, students found the writing exercises to be the change they loved to hate. There were reactions of extreme dislike and resentment. For example, one student wrote: "I hated [the writing.] I thought we were supposed to learned math not developed our writing skill" [sic]. Students complained the questions were "vague," "mind-wrenching," "why would a teacher want to confuse [us?]," and that their use just proved that "math was harder than other subjects." The most common complaint was that they were just too much work.

However, whether or not it was just a desire to write something to please a teacher who had instituted seemingly painful changes, there were also a number of grudging admissions that although the writing was hard work, it was worthwhile. "I [now] feel more comfortable when I have to explain in words...however some of them gave me big headaches." In particular, second language learners would, along with complaints about the unfairness of and difficulty engendered by assigning the written work in a math course, admit that the practice of explaining ideas in English was useful training. One of the most touching comments came from a student who struggled to get a "D" in the course. She said, "This class is not easy for me because English is not my first language...it is interesting that even though [people] may speak different languages the math is the same." Another, a non-education major, offered that "the most precious thing is I learned how to explain a math idea with words and examples...it helped me improve my communication skills." A favorite quote comes from a student who earned a grade of "B" and who began the course proclaiming that math had always been her worst subject. She stated that the writing exercises "forced me [her] to think...helped me [her] to see my [her] weaknesses...helped me [her] to write more clearly and stick to the point." We rest our case!

At this point the gentle reader might be ready to ask why the attitudes scores were not actually **higher** (more negative) in the reform classes. The statistical analyses indicated that the students in the reform courses felt somewhat more confident than the control students. There were some changes that the vast majority of the students did find positive. The full-period activities, each covering one of the topics of set theory, number bases, primes/factors/multiples and probability were immensely popular. Students agreed fairly consistently that the activities were "creative and fun" and "without them I would have done much worse in this class." The activities helped them to "feel more comfortable with math" because they could "really see what was going on." The collaborative aspect of activities was also popular. The group interaction was helpful in ameliorating the difficulty some students had in communicating ideas in English. (All group discussions were to be held in English.) Some were pleased to "get to know one another since we are all future teachers," an untrue statement since non-education students comprised about 20% of the class. A few members of this latter group did not approve of the activities as wholeheartedly. One such student said that he felt that "in the activity, people are involved but concentrating on the activity but not the meaning." However, he admitted that lecture did not provide a more effective platform since "students were [mostly] a passive audience." He mentioned being "bored with a simple activity." Another, an international student, found the behavior of the other members of his group to be distracting and unhelpful. However, the majority of the students praised the activities and desired that more of the class be devoted to this type of exercise. However, several noted that the required written follow-up questions spoiled the pleasure of the activities.

Thus we may ask, what can we conclude from the study and about the effectiveness of the reform? The formal student evaluations of the first author shed some light on this issue. The ratings range from 1 to 5 with 1 meaning 'one of the worst,' 5 'one of the best,' and 4 'better than average.' Ring's scores for the questions that ask students to rate the course and the instructor have very rarely averaged, for any course, below 4. In fall 1996, when the requirements of the course were only journal entries and simple activities, the course and instructor were rated 4 and 4.5, respectively. By spring 1997, when the course was in the full flower of its reform and requirements, those ratings had fallen to 3.4 and 3.7, respectively, the **lowest that she has ever received in any course.** Attitude studies, taken of all students in a class, give a simplified answer to a complex question. What empowers and delights students is often dependent on many factors. In particular, it depends on the demands being made on the students and the resources these students may have at their disposal to meet these demands. It is interesting to note that the most positive comments on the course are those submitted by "A" and "B" students, those with the least to gain by "buttering-up" their instructor. The grades in Math 185 (both the 'original' and the 'new and improved' course) are generally lower than almost any other mathematics course at the College. The education students seem to have many outside commitments and obligations to juggle with their schoolwork. The revised course demands stronger language skills than a conventional math course and the students feel cheated when they are required to "do English" as well as math. It will require a number of years and the gradual solidification of the new requirements by the College and State Education Departments until our students can truly address the challenges of developing the profound understanding, along with the enjoyment, of elementary mathematics needed by the teachers of tomorrow's citizens.

Recommendations

There are several recommendations that we feel result from this study. First, reform of mathematics courses on the college level is difficult unless the prerequisite skills are attended to. Those studies reviewed that accounted for prerequisite skills by providing a sequence of courses (Gibson et al., 1999; McDevitt et al., 1993) resulted in more positive findings related to students' attitudes toward mathematics and mathematics teaching. In the present study, students, often limited-English proficient, were asked to explain their understandings of "advanced" mathematical ideas without appropriate understanding of basic mathematics. These students found this very difficult for at least two reasons: they have never been asked to explain their mathematical reasoning and they had difficulty with English. However, they indicated anecdotally that this helped them to feel more secure, potentially resulting in the higher confidence scores on the attitudinal questionnaire.

Second, Math 185 was and is firmly entrenched in the mathematics department serving both education and other majors and culminating with a departmental final. Thus, while strong inroads to reform were made, the elements implemented increased the burden of the students and instructor without lessening the burden of content. The instructional strategies implemented may have helped students understand the mathematics better, but without increased time to interact with them, the students and instructor felt pressured by the curriculum. We hold that this was a truly successful reform in spite of a very full curriculum.

Third, working within such a context, we need to ask ourselves how changes developed by one professor might become institutionalized. In this example, this occurred in two ways: the chair mandated the use of activities in all sections and the New York Department of Education mandated a second mathematics course for education majors. In the first case, we are left with the question as to whether a mandated curriculum can be successful without ample faculty support for the changes. We wonder how these activities have been implemented following Ring's work with the faculty. Hinton (1997), within the context of another NSF funded Collaborative for Excellence in Teacher Preparation investigated administrative impediments to reform. This author found that systemic change was dependent upon administrative support, from the department chair to the university president. The efforts of a few dynamic faculty members may be lost without consistent support and administrative leadership. Pape and Tittle (1999) found similar administrative impediments in their investigation of evaluation of systemic change. In addition, Feren and McCafferty (1992) suggest that their needs to be several support structures for students and faculty in order for reform at the college level to be successful. They suggest that universities must support students through improved placement (i.e., placement in courses that are appropriate for individual students), relevant curriculum, committed tutoring, and strengthening teaching. In the present study, Ring lobbied for a second course to prepare her students to undertake the process of learning more "advanced" mathematical concepts. However, it was not until the state mandated a second course that it was implemented.

Finally, attitudes toward mathematics are based on long-term interactions with the subject and mathematics teachers. They take a long time to develop and are hard to change. One semester's efforts to impact these attitudes may be thought of as feeble at best. However, Simon and Schifter's (1993) work with inservice teachers provides hope that if we can impact teaching on the elementary level, we are more likely to change the attitudes of their students. We believe that this is important work that needs to be continued in order for long-term systemic change to occur.

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Table 1

Timeframe for the implementation of the reform and study components

Semester	Element of Reform Implemented	Study Component Implemented
Spring 1996	Classroom journals (attitudinal; understanding of and reaction to course topics Math Autobiography	
Fall 1996	Classroom journals (as above) Math Autobiography Cooperative learning problem-solving sessions Use of manipulative materials within activity based lessons	1 reformed class (Ring) 2 control classes
Spring 1997	Classroom journals (as above) Math Autobiography Final course summation Written explanations of thought questions, class activities, and exam questions Cooperative learning problem-solving sessions Use of manipulative materials within activity based lessons Twelve brief collaborative learning exercises	1 reformed class (Ring) 1 control class
Fall 1997	All instructors encouraged to incorporate activities	2 reformed classes 1 control class
Spring 1998	Chair mandates use of activities in all sections (Ring assisted implementation of activities in all courses) NYS Department of Education mandates two math courses for all elementary education majors	
Fall 1998	Requirements changed to include a QR course to precede Math 185	

Table 2

Reliability Estimates

	Fall 1996 (N = 43)	Spring 1997 (N = 30)	Spring 1998 (N = 39)	3 Semesters (N = 112)
Total Scale (36 items)	0.8994	0.8802	0.9085	0.8986
Confidence & Anxiety (12 items)	0.8904	0.8763	0.9022	0.8924
Subscales (6 items each)				
Confidence (CONF)	0.7934	0.7923	0.7999	0.7964
Attitude (AS)	0.3896	0.7094	0.5288	0.5477
Male Domain (MD)	0.4835	0.7446	0.4313	0.5592
Usefulness (USE)	0.7176	0.6820	0.8193	0.7468
Anxiety (ANX)	0.8340	0.7839	0.8347	0.8235
Effectance Motiv (EFF)	0.6406	0.4832	0.7550	0.6636

Table 3

Mean Scores (SD) for the Total Sample, Treatment, and Control Groups on Each Subscale Over the Two Times of Assessment.

	Total Sample		Treatment Group		Control Group	
	T1	T2	T1	T2	T1	T2
Total score	81.20 (17.88)	78.82 (20.07)	78.83 (18.87)	75.59 (19.17)	83.74 (16.55)	81.91 (20.72)
Confidence/ Anxiety	32.86 (10.23)	31.28 (10.44)	32.45 (10.83)	30.36 (9.99)	33.30 (9.63)	32.26 (10.91)
Subscales (6 items each)						
Confidence	14.82 (5.28)	13.69 (5.36)	14.78 (5.27)	12.93 (5.08)	14.87 (5.33)	14.50 (5.58)
Attitude	11.30 (3.50)	11.16 (3.67)	10.60 (3.48)	10.38 (3.69)	12.06 (3.40)	12.00 (3.50)
Math as a male domain	9.71 (3.22)	10.22 (3.68)	9.53 (3.03)	9.67 (3.45)	9.91 (3.42)	10.81 (3.86)
Usefulness of math	11.88 (4.25)	11.66 (4.32)	11.22 (4.48)	11.33 (4.34)	12.59 (3.90)	12.02 (4.31)
Anxiety toward math	18.04 (5.50)	17.59 (5.69)	17.67 (6.04)	17.43 (5.47)	18.43 (4.87)	17.76 (5.97)
Effectance motivation	15.44 (4.36)	14.50 (4.60)	15.02 (4.67)	14.21 (4.79)	15.89 (3.99)	14.81 (4.41)

Note: T1 = time 1, beginning of semester; T2 = time 2, end of semester.

Appendix A

DIRECTIONS

MATHEMATICS ATTITUDE SCALE

On the following pages is a series of statements. There are no correct answers for these statements. They have been set up in a way, which permits you to indicate the extent to which you agree or disagree with the ideas expressed.

Suppose the statement is:

1. I like mathematics.

As you read the statement, you will know whether you agree or disagree. If you strongly agree, blacken circle A opposite Number 1 on your answer sheet. If you agree but with reservations, that is, you do not fully agree, blacken circle B. If you disagree with the idea, indicate the extent to which you disagree by blackening circle D for disagree or circle E if you strongly disagree. But if you neither agree nor disagree, that is, you are not certain, blacken circle C for undecided. Also, if you cannot answer a question, blacken circle C. Now mark your answer sheet. Do the same for example No. 2.

2. Math is very interesting to me.

Do not spend much time with any statement, <u>but be sure to answer every statement.</u>
Work fast but carefully.
There are no "right" or "wrong" answers. The only correct responses are those that are true <u>for you.</u> Whenever possible, let the things that have happened to you help you make a choice. Do not mark on the booklet.
THIS INVENTORY IS BEING USED FOR RESEARCH PURPOSES ONLY AND NO ONE WILL KNOW WHAT YOUR RESPONSES ARE.

3. Generally I have felt secure attempting mathematics.
4. I don't like people to think I'm smart in math.
5. Girls can do just as well as boys in mathematics.
6. I see mathematics as a subject I will rarely use in my daily life.

7. I have usually been at ease during math tests.
8. Figuring out mathematics problem does not appeal to me.
9. It would make people like me less if I were really a good math student.
10. My mind goes blank and I am unable to think clearly when working in mathematics.
11. Mathematics is enjoyable and stimulating to me.
12. Studying mathematics is just as appropriate for women as for men.
13. Math has been my worst subject.
14. I'll need mathematics for my future work.
15. I can get good grades in mathematics.
16. Girls who enjoy studying math are a bit peculiar.
17. Being regarded as smart in mathematics would be a great thing.
18. Taking mathematics is a waste of time.
19. I haven't usually worried about being able to solve math problems.
20. I don't understand how some people can spend so much time on math and seem to enjoy it.,
21. Males are not naturally better than females in mathematics.
22. When a question is left unanswered in math class, I continue to think about it afterward.
23. I'm not the type to do well in math.
24. People would think I was some kind of nerd if I got A's in math.
25. Mathematics is a worthwhile and necessary subject.
26. I usually have been at ease in math classes.

27. I would expect a woman mathematician to be a masculine type of person.
28. I am sure that I can learn mathematics.
29. I'd be proud to be the outstanding student in math.
30. Mathematics is of no relevance to my life.
31. I get a sinking feeling when I think of trying hard math problems.
32. It would be really great to win a prize in mathematics.
33. I study math because I know how useful it is.
34. I would have more faith in the answer for a math problem solved by a man than a woman.
35. I'm no good in math.
36. When a math problem arises that I can't immediately solve, I stick with it until I have the solution.
37. Mathematics usually makes me feel uncomfortable and nervous.
38. I would rather have someone give me the solution to a difficult math problem than to have to work it out for myself.

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